

IEP Monitoring Plan Review
Zooplankton Component
DRAFT
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This report describes and supports the recommendations of the zooplankton subgroup for amendments to the existing zooplankton monitoring program.

The fundamental principles and conceptual framework for monitoring zooplankton are laid out in the CMARP technical appendix for system productivity at the base of the food web (<http://...>). The purposes of the monitoring program and of this review are described in (document).

Continuing to monitor zooplankton in the estuary can be justified mainly on the basis of understanding the ecology of the estuary. We believe that better understanding can make managing the estuary and human uses of it are well served by a firm grasp of the function of the estuarine ecosystem. Zooplankton are important to this function in a number of respects. First, zooplankton are a key element of the foodweb, essential in transferring energy produced at the base of the foodweb to young fish. There is growing evidence that various fish species are food-limited early in life, and zooplankton abundance has declined over the last 2 decades in much of the estuary. Second, zooplankton monitoring has been essential for detecting changes in the system due to introductions (e.g., the apparent effect of the introduced clam *Potamocorbula* on several fish species). Third, zooplankton are the smallest organisms that can be readily and reliably identified under a microscope by a reasonably well-trained technician. This means that they make excellent indicators of conditions such as salinity effects, water movement, and energy supply for fish and other organisms.

Principles

1. The zooplankton monitoring program is being adjusted, not designed from the ground up. Therefore the first principle is to ensure continuity in the data collected.
2. We assume that substantial additional funds for monitoring are not available in the short term. Therefore major new efforts (e.g., additional sample types) are not being recommended here. The CMARP appendix contains several recommendations for pilot studies which are reiterated below.
3. The SAG has recommended that the zooplankton monitoring program extend into the lower estuary, and a pilot study has been completed (report being revised). Although this expansion has not been approved, we assume that this will happen in the near future.

Current monitoring program

The current monitoring program as described by Orsi and Mecum (1986) has been modified by: 1) a reduction in the number of stations; 2) addition of two stations based on salinity; 3) reduction of surveys from 2 per month in some months to one per month; 4) extension of sampling into December-February; and 4) joining of field efforts with the shipboard water quality program. Here we describe the program as it now exists.

Stations and frequency: Surveys are conducted monthly using R/V San Carlos. Stations are in San Pablo Bay, Carquinez Strait, Suisun Bay, the Sacramento River below Rio Vista, the San Joaquin River upstream to Stockton, and the southern Delta in Old River (Figure 1). At present 16 stations are visited on a regular basis, plus two more stations that “float” at conductivity of 2 and 6 mS/cm.

Sampling: At each station, Secchi depth is recorded, and surface conductivity and temperature are measured with a Seabird CTD. Where surface conductivity exceeds 1 mS cm^{-1} , bottom conductivity and temperature are also measured. Samples for chlorophyll are taken as described in the water quality program.

Zooplankton samples are taken with three types of sampling gear: a macrozooplankton net, a Clarke-Bumpus net and a pump. The macrozooplankton net (referred to in the program as a Neomysis net) is 1.5 m long with a mouth diameter of 30 cm and a mesh of 0.505 mm nylon, and is mounted on a sled with a steel frame. A General Oceanics flowmeter is mounted in the mouth of the net. The Clarke-Bumpus net, 10 cm in diameter and 73 cm long, of 0.153 mm mesh, is mounted on top of the macrozooplankton net. It has its own internal flowmeter. The paired net system is deployed in a 10-minute stepped oblique tow from the bottom to the surface, and samples are preserved in 10% formaldehyde with Rose Bengal stain added.

The pump has a capacity of 15 L min^{-1} and a weighted 15-meter hose. The intake of the hose is slowly raised from the bottom or 15 meters to the surface while pumping into a carboy. A subsample of 1.5-1.9 L is drawn from the carboy and preserved in 10% formaldehyde with Rose Bengal stain.

Sample processing: Macrozooplankton samples are spread evenly in a square tray equipped with removable partitions for subsampling. Samples estimated to have more than 400 specimens are divided into 4, 16, or 64 subsamples. All mysids in a selected subsample are counted, measured to the nearest millimeter from the eye to the base of the telson, and identified to life stage, sex, and gravid or non-gravid. In recent years amphipods (*Gammarus daiberi*, *Corophium* spp.) Have also been counted.

Clarke-Bumpus samples are subsampled using an automatic pipette and counted in a Sedgwick-Rafter cell under a compound microscope. Subsamples are repeated until at least 200 animals have been counted. Pump samples are processed by recording the sample volume, then concentrating the sample by pouring it through a cup with 154 μm mesh followed by one with 43 μm mesh. The organisms retained by the 43 μm mesh are counted as for the Clarke-Bumpus sampler and those larger than 154 μm are discarded, since the net sample is assumed to capture that fraction quantitatively.

Data from all samples are reported as abundance in number m^{-3} .

Data reporting: Data are entered using SAS (Statistical Analysis System) and have been reported in two formats: a flat file, in which each taxon and life stage is reported in a separate

column and each row contains all ancillary data relevant to the sample; and a relational database format in which field data are reported in one table and zooplankton data in other tables. Each taxon/life stage combination is given a unique alphabetic code; for example, *Pseudodiaptomus forbesi* adults are reported as PDIAPFOR, and copepodites as PDIAPCOP. Links between tables are made through the survey and station number so that field data can be connected to abundance data.

Mysid data are reported separately from zooplankton data; at present no other macrozooplankton (e.g., amphipods, gelatinous plankton) are included in data tables. Data from pump samples and Clarke-Bumpus samples are added together before they are reported.

Recommendations for change

We reiterate that the guiding principle behind any changes to the program is that continuity should be maintained. Changes recommended here are therefore not expected to diminish the reliability of the long-term data set. The recommendations are listed below, then discussed and justified. Recommendations for research and pilot studies are in the next section.

4. Add the Hood station (C3) back to the monitoring program
5. Investigate whether the sampling frequency aliasing the tidal cycle causes erroneous signals to creep into the data.
6. Extend the program into the lower estuary
7. Consider using larger nets to reduce sampling time, and conduct trials to calibrate between the larger and smaller nets.
8. Increase pump sampling volume and improve sample processing and reporting.
9. Consider not using stain on samples from higher salinity regions of the estuary.
10. Count and report all large zooplankton in the macroplankton samples.
11. Consider identifying some meroplankton to species.
12. Refine the data reporting system to increase its utility.

Stations and frequency (Items 1-3): At present no samples are taken from the Sacramento River above Decker Island (river kilometer 90). The Hood station is sampled for water quality from a van rather than a boat, since this station is so far upstream (river kilometer 139). This is a valuable station that indicates the concentration of zooplankton entering the delta from upstream. We believe it should be added back to the program, perhaps by the use of a shore-based pump sampler (see below). A similar justification can be used for a station on the San Joaquin River at Mossdale.

The current monthly frequency aliases the spring-neap tidal cycle. However, it would be premature to go to some other frequency, because monthly sampling has logistical advantages. Therefore a special study is recommended (see below) to investigate the potential for bias in the data.

We follow the SAG's recommendation of several years ago to urge the IEP to extend the zooplankton sampling into the lower estuary. Station locations (12 stations) have been recommended on the basis of the pilot study. These are Bay Study stations, under the assumption that the Bay Study would be able to take these samples in their existing program. For continuity with the current program, however, the samples recommended for San Pablo Bay should be changed somewhat.

We discussed but did not resolve the possibility of a station outside the mouth of the estuary. This would be very helpful in providing an endpoint for comparison with bay samples, but it is not clear how far out the mouth the station would have to be located to provide this function, since the actual mouth of the estuary may be the shoal in the Gulf of the Farallones.

The major issue to be decided in extending the study is how to deal with the additional time required to take these samples. In order to include the macroplankton portion of the program, it is necessary to continue sampling with relatively large nets. At present each of these samples takes 10 minutes. Assuming another 10 minutes for preparation, washing nets, pump sampling, and switching between nets, 12 zooplankton samples would take approximately 4 additional hours. Adding a half day to the Bay Study sampling program may be expensive; thus, we offer some alternative ideas about sampling below.

When the zooplankton monitoring is expanded into the lower estuary, provision should be made for collecting chlorophyll samples at the same stations as the zooplankton samples. Whole chlorophyll and chlorophyll larger than 10 μ m should be analyzed using the methods now applied in the water quality monitoring program.

Sampling methods (Items 4-5): The current method of sampling the microzooplankton is inadequate and needs to be revised. The sample size is too small to provide reliable abundance estimates. We recommend changing to a pump system using a relatively large-volume submersible bilge pump discharging through a hose and pipe system into a small plankton net. An inline flowmeter can be used to determine volume filtered quite accurately. This system was used to sample small zooplankton during the Grizzly Bay study, and it proved very easy to use and highly reliable. Although the bilge pumps are not designed to be lowered much below the surface, they perform well down to at least 20 meters as long as they are not handled too roughly. Using a bilge pump with a nominal pumping rate of 2400 gallons/hour, this method would provide sample volumes of about 0.5 m³ in 3 minutes. Pumping rate would need to be tested to see if it changes with depth.

The current practice of staining samples when they are taken ensures that the zooplankton can be readily distinguished from detritus in the samples. However, for the lower estuary, staining may obscure features useful in identification and is not necessary since detritus is less abundant. This needs to be determined when IEP personnel are trained to identify these additional taxa of zooplankton.

A change in sampling methods should be made in a long-term program only for very good reasons, and after careful analysis. Extending the sampling to the lower estuary does not necessarily require using the same methods, provided they are comparable. The pilot study showed the use of a 1/2 meter net gave similar results to the Clarke-Bumpus net. We estimate that using current methods, and including the entire suite of measurements, will cost about half a day per survey, as discussed above. There are several alternative approaches:

1. Bite the bullet and accept the 4-hour added time, using the existing equipment. **Pros:** no change to sampling method, maintains continuity. **Cons:** expensive in boat and crew time.
2. Take samples only for small zooplankton in the lower estuary. This would allow the other zooplankton samples to be taken by vertical haul, greatly reducing the time and adding only minutes to the surveys. However, in the upper estuary mysids and other macrozooplankton appear to be quite important in the foodweb, and this may be true

seaward as well. Based on the limited sampling for mysids done in the lower estuary during the pilot study, overall abundance appears to be roughly comparable to what it is in Suisun Bay and the delta. Thus, ignoring these creatures in the lower estuary would cause us to miss a potentially important link in the foodweb. **Pros:** little additional time to sample. **Cons:** no data on a potentially important component.

3. Take macrozooplankton samples only at a few stations. This would reduce the sampling effort and time required, but also increase the variability in the estimates of abundance. Although we have not determined the magnitude of this variability, it is likely to be at least on the same order of magnitude as the mesozooplankton. Since mysids, amphipods, and some other macrozooplankton tend to be distributed close to the bottom, small differences among stations in the amount of time the net is actually on the bottom can lead to large differences in abundance. **Pros:** reduces the additional time to ~ 2 hours per survey. **Cons:** high uncertainty in abundance estimates.
4. Use larger nets and tow for a shorter time. For example, a meter net (standard oceanographic equipment) has about 11 times the mouth area as the current macrozooplankton net, and could be towed for just the time it takes to get the net from the surface to the bottom and back. The smaller zooplankton could then be collected with a vertical tow or a very short oblique tow at shallow stations (using a ½ meter net, a 1-minute tow would collect an adequate sample of zooplankton). The alternative macrozooplankton net would have to be tested in a side-by-side comparison with the existing equipment. This should be done in several seasons (for different species), several locations, and under different hydrologic conditions. If this change in methods works satisfactorily IEP may want to consider using this method throughout the estuary to reduce the tow time. However, it may not be essential to use the same methods in both regions, provided they are reasonably comparable. **Pros:** reduces the additional time to ~ 2 hours per survey. **Cons:** need to cross-calibrate, and possibly accept some calibration error.

Sample processing (Items 6-8): If the pump sampling system is changed, pump samples will need to be processed using the same methods as for the zooplankton net samples.

At present the focus of the macroplankton sample analysis is on mysids. However, there are numerous other taxa that are captured reliably by this net, especially young stages of shrimp (e.g., *Palaeomon*), amphipods, large copepods, and gelatinous zooplankton. Large copepods and gelatinous plankton are uncommon in the upper estuary but can be abundant further seaward. The procedures used to process these samples should be amended so that these other taxa are identified to species and counted.

Meroplankton, larvae of benthic species, are not identified to species, and doing so routinely for all taxa is probably not cost-effective. However, some meroplanktonic forms have not been reported in the IEP zooplankton data yet they are probably abundant. Notably this includes bivalve larvae. Furthermore, if certain species can be routinely identified (e.g., mitten crabs, *Potamocorbula*) they should be included as separate taxa. In the lower estuary, microplankton samples will contain large numbers of tintinnid protozoa, which are important members of the foodweb that should be identified to the level possible and counted.

More generally, the technicians responsible for counting samples should be on the lookout for new or different taxa. This is not a comment on past practice, as the IEP zooplankton monitoring program has promptly documented several introductions. However, with the

additional taxonomic diversity and the connection to the ocean, this task will be more difficult. Unusual species will be particularly common in the Central Bay samples, which may contain numerous oceanic vagrants. Although it may not be necessary to identify every species on a routine basis, at least they need to be identified and recorded as something different. This can be done most easily using a letter system (e.g., unidentified calanoid copepod A), provided voucher specimens are kept and an accurate description of each new species is made.

Data reporting (Item 9): The reporting system needs to be made more accessible to outside users. The flat-file format previously used is no longer suitable because it is inflexible with regard to added species. However, the species code system is also rather cumbersome because the names do not sort taxonomically, and there is no clean method for combining life stages of a single species, or combining groups of species. In addition, as more taxa and life stages are added, the system will become increasingly cumbersome. This system should be replaced by one that includes taxonomically-oriented numeric species codes and separate life stage codes. This would make it easy to extract, for example, all copepod nauplii, all calanoid copepod adults, or all meroplankton.

The pump data must be reported separately from the net data instead of being added together. The two sampling methods have very different thresholds, with the result that occasional single organisms in the pump samples result in anomalously large abundance values. Although this problem will be partially alleviated by the pump sampling method recommended above, the effective volume sampled, including effects of subsampling, will always be much smaller in the pump sample than the net sample. Thus, these two samples are not directly comparable.

Pilot and special studies

The CMARP appendix on lower trophic level productivity recommended the following additional monitoring or ancillary studies not discussed above:

- \$ Estimates of biomass (or biovolume as an alternative) should be a routine component of monitoring. This could be done using existing methods with the addition of estimates of weight per life stage and species.
- \$ Microzooplankton should be analyzed in a pilot study to determine whether and how to monitor their abundance routinely.
- \$ If gelatinous zooplankton prove to be abundant, and preliminary calculations reveal their predatory rates could be significant, experiments to determine these rates should be conducted.
- \$ Zooplankton secondary production should be estimated by combining biomass estimates (above) with less frequent estimates of growth rate.

Additional pilot or special studies that would complement the monitoring program, as discussed above are:

- \$ Comparison of different net samplers, if a change in samplers is considered.
- \$ Analysis of effects of aliasing of the spring-neap signal on seasonal patterns from monthly samples, and other potential timing issues.
- \$ Day/night sampling to determine effectiveness of routine daytime monitoring.

Finally, current station identification and numbering schemes are at least as abundant as different sampling programs. A new station identification scheme should be devised that will apply to all programs. This extends far beyond the zooplankton monitoring program

and applies throughout IEP.